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Analysis of published data for standardized ileal digestibility of protein and amino acids in soy proteins fed to pigs[1]

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ABSTRACT: The present work was conducted to determine, via a summary of data from peer-reviewed publications, if differences in the standardized ileal digestibility (SID) of CP and AA in different soy proteins exist when fed to pigs and to determine if the BW of pigs influences the SID of CP and AA. The following ingredients were included in the analysis: dehulled soybean meal (SBM) with 46 to 48% CP (SBM 48%), non-dehulled SBM with a CP concentration of 42 to 44% (SBM 44%), enzyme-treated SBM (ESBM), fermented SBM (FSBM), soy protein concentrate (SPC), and soy protein isolate (SPI). Results indicated that the SID of most AA was not different between SBM 48% and SBM 44%; however, for some AA, greater ($P < 0.05$) SID values in ESBM, SPC, and SPI were obtained compared with SBM 48%, SBM 44%, and FSBM. The least ($P < 0.05$) SID of Lys was observed in FSBM, which also had the least Lys-to-CP ratio, indicating that FSBM sometimes is exposed to excessive heat damage during drying of the fermented product. For SBM 48%, it was also possible to analyze the effect of pigs' BW on the SID of CP and AA. Results indicated that the SID of CP and AA were less ($P < 0.05$) in pigs of BW less than 20 kg compared with pigs of BW above 20 kg. Therefore, it can be concluded that differences in SID of CP and AA among soy proteins exist and that for SBM 48%, SID values may be less in pigs less than 20 kg than in pigs above 20 kg.

Key words: amino acids, body weight, pigs, soybean meal, soy protein concentrate, soy protein isolate

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INTRODUCTION

Soybean meal (**SBM**) is the most commonly used protein source in diets fed to pigs because the balance of AA in soy protein complements the AA in most cereal grains, resulting in balanced complete diets being formulated (Stein et al., 2008). Soybeans may or may not be dehulled before crushing (NRC, 2012), resulting in production of dehulled SBM with 46 to 48% CP (**SBM 48%**; as fed) and non-dehulled SBM with a CP concentration of 42 to 44% (**SBM 44%**; as fed), respectively. However, for newly weaned pigs, further processed soybean products such as enzyme-treated SBM (**ESBM**), fermented SBM (**FSBM**), soy protein concentrate (**SPC**), or soy protein isolate (**SPI**) are sometimes preferred because of the reduced concentrations of antinutritional factors in these sources of soy protein (Cervantes-Pahm and Stein, 2008, 2010).

In addition to having a high concentration of indispensable AA, the standardized ileal digestibility (**SID**) of CP and AA is greater in soy protein than in most other plant-based proteins (Sauvant et al., 2004; CVB, 2012; NRC, 2012). However, in most feed ingredient databases, the same values for the SID of CP and AA are used for all categories of pigs (Sauvant et al., 2004; CVB, 2012; NRC, 2012), although it has been hypothesized that SID values for AA may be reduced in newly weaned pigs compared with growing or finishing pigs (Urbaityte et al., 2009). For most feed ingredients, limited data with pigs less than 20 kg have been reported, but for a number of soybean ingredients, values for weanling pigs have been reported, and for SBM 48%, values for weanling pigs as well as older pigs are available. It is, therefore, the

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objective of this contribution to 1) determine if differences in SID of CP and AA among different sources of soy protein exist and 2) determine if the SID of AA in SBM 48% is affected by the BW of pigs.

MATERIALS AND METHODS

Literature Search

The data used for the analysis include data published in peer-reviewed journals from 1998 to 2013. Data from the following journals were included: *African Journal of Agricultural Research*, *Animal Feed Science and Technology*, *Animal*, *Archives of Animal Nutrition*, *Asian-Australasian Journal of Animal Sciences*, *Biocatalysis*, *Revista Brasileira de Zootecnia*, *British Journal of Nutrition*, *Canadian Journal of Animal Science*, *Journal of Animal Physiology and Animal Nutrition*, *Journal of Animal Science*, *Journal of the Science of Food and Agriculture*, *Livestock Science*, *Livestock Production Science*, and *The Professional Animal Scientist*. A summary of data for all ingredients organized by geographical origin is available in the Feed Ingredient Database published at http://nutrition.ansci.illinois.edu/). The Feed Ingredient Database provides information on the number of observations included in the mean, the SD, the minimum and maximum values, nutrient concentration, and digestibility of CP and AA for each ingredient.

The soybean ingredients for which data were available included SBM 48%, SBM 44%, ESBM, FSBM, SPC, and SPI. For each ingredient, data for SID of CP and AA and starting BW of the pigs at the time the experiment was conducted were recorded. For most ingredients, SID values for all AA were available, but if data for only apparent ileal digestibility were published, these values were transferred to values for SID using an average value for the basal endogenous loss of each AA. For ESBM, FSBM, and SPI, all observations were obtained in pigs with a starting BW of less than 20 kg, whereas data for the remaining ingredients included results from some experiments in which the BW of pigs was greater than 20 kg. For SBM 48%, it was possible to divide data among weanling pigs that were less than 20 kg, growing pigs (20 to 50 kg), and finishing pigs that were greater than 50 kg, but for the other ingredients, there were no or very limited data from pigs with an initial BW greater than 50 kg.

Data Analysis

Data were analyzed by ANOVA using PROC MIXED of SAS (SAS Inst. Inc., Cary, NC). The statistical model included ingredient (i.e., source of soy protein) as the fixed effect. Treatment means were calculated using the LSMEANS statement and means were separated using the PDIFF option of PROC MIXED. In the first analysis, all data were included regardless of pig BW. A second analysis was conducted on data for the SID of CP and AA in SBM 48% by dividing data into 3 groups based on the BW of pigs used to generate the data (i.e., less than 20 kg, 20 to 50 kg, and greater than 50 kg). The main effect of BW on values for SID of CP and AA in SBM 48% was analyzed by ANOVA.

RESULTS AND DISCUSSION

The SID of CP in SPC was greater ($P < 0.05$) than in SBM 48% and FSBM and the SID of CP in ESBM was greater ($P < 0.05$) than in FSBM (Table 1). The SID of Lys was greater ($P < 0.05$) in SPC and SPI than in SBM 48% and in FSBM but not different from ESBM and SBM 44%. However, FSBM had the least ($P < 0.05$) SID of Lys among all ingredients. The reason for this observation is most likely that FSBM sometimes is overheated during the drying process, which may result in Maillard reactions and a subsequent reduction in the SID of Lys (González-Vega et al., 2011). For some sources of FSBM, this assumption was supported by a value for Lys as a percentage of CP that was less than 6.0, which is indicative of heat damage in soy protein (González-Vega et al., 2011).

No differences in SID of indispensable AA among ESBM, SPC, and SPI were observed, and with the exception that the SID of Asp was less ($P < 0.05$) in SPC than in SPI, no differences among these 3 ingredients were observed among the dispensable AA. The SID of Arg, Leu, Phe, and Val was greater ($P < 0.05$) in ESBM than in SBM 48%, SBM 44%, and FSBM, and the SID of Glu in ESBM was also greater ($P < 0.05$) than in FSBM. The SID of Arg, Leu, Phe, and Val in SPC was greater ($P < 0.05$) than in SBM 48% and SBM 44%, and the SID of Ala, Glu, Gly, and Ser in SPC was greater ($P < 0.05$) than in SBM 48% and in FSBM. Likewise, the SID of Asp and Glu in SPI was greater ($P < 0.05$) than in SBM 48%, SBM 44%, and FSBM, and the SID of Ala and Ser in SPI was also greater ($P < 0.05$) than in SBM 48% and FSBM. These observations indicate that processing to remove antigens, lectins, oligosaccharides, and other carbohydrates may have a positive impact on the SID of AA in pigs. Further processing of SBM to produce FSBM, ESBM, SPC, or SPI is done primarily to improve the tolerance for soy protein by young pigs during the initial 3 to 6 wk after weaning, and the present data indicate that this results in an improved SID of some AA in some of the further processed sources of soy protein. However, as was indicated by the SID for FSBM, further processing may also result in reduced SID of Lys due to heat damage.

Table 1. Standardized ileal digestibility (%) of CP and AA of dehulled soybean meal with 46 to 48% CP (SBM 48%), non-dehulled soybean meal with a CP concentration of 42 to 44% (SBM 44%), enzyme-treated soybean meal (ESBM), fermented soybean meal (FSBM), soy protein concentrate (SPC), and soy protein isolate (SPI)[1]

Item	SBM 48%			SBM 44%			ESBM			FSBM			SPC			SPI				
	$\bar{x}$	No.	SD	$\bar{x}$	No.	SD	$\bar{x}$	No.	SD	$\bar{x}$	No.	SD	$\bar{x}$	No.	SD	$\bar{x}$	No.	SD	SEM	*P*-value
CP	85.5^{bc}	101	5.4	85.8^{abc}	16	3.6	89.5^{ab}	4	2.5	83.0^{c}	7	4.1	89.0^{a}	12	1.2	88.2^{abc}	5	5.1	2.4	0.05
Indispensable AA																				
Arg	93.3^{b}	117	3.3	92.5^{b}	25	3.6	96.9^{a}	4	2.3	92.3^{b}	7	2.9	95.5^{a}	14	1.8	94.4^{ab}	6	4.1	1.5	0.02
His	88.3	116	5.3	88.0	26	4.7	92.5	5	3.8	86.3	7	4.1	90.8	14	2.6	87.9	6	6.7	2.3	0.17
Ile	88.0	117	4.3	88.5	26	4.4	91.4	5	2.5	86.8	7	4.1	91.1	14	2.6	87.6	6	9.6	2.0	0.10
Leu	86.7^{c}	117	4.0	86.8^{c}	26	3.9	91.8^{a}	5	2.8	87.2^{bc}	7	4.4	90.2^{ab}	14	2.5	89.2^{abc}	6	6.1	1.8	<0.01
Lys	87.8^{b}	117	4.0	88.6^{ab}	26	3.3	88.1^{ab}	5	0.5	81.7^{c}	7	6.3	90.9^{a}	14	2.7	91.2^{a}	6	3.9	1.7	<0.01
Met	88.9	111	4.8	89.9	22	4.4	92.8	4	1.7	90.1	7	2.1	91.7	13	2.9	86.2	5	12.1	2.4	0.13
Phe	87.7^{c}	116	3.5	87.4^{c}	26	3.3	92.3^{a}	5	2.7	86.6^{bc}	7	6.1	89.9^{ab}	14	3.1	88.1^{abc}	6	6.1	1.6	0.03
Thr	83.0	117	6.0	83.8	26	5.5	87.0	5	3.4	81.7	7	6.5	85.4	14	3.9	82.5	6	8.4	2.6	0.45
Trp	86.3	93	8.4	89.7	17	3.6	89.5	4	4.6	86.1	7	6.7	88.3	11	3.2	87.1	2	2.9	5.3	0.55
Val	85.4^{c}	117	4.8	85.2^{c}	26	3.4	91.3^{a}	5	3.5	85.7^{bc}	7	4.7	89.3^{ab}	14	2.8	86.0^{abc}	6	10.2	2.1	<0.01
Dispensable AA																				
Ala	83.5^{b}	92	5.8	86.3^{ac}	21	5.0	88.4^{ab}	4	1.9	83.5^{bc}	7	3.8	88.9^{a}	13	2.6	89.7^{a}	5	4.2	2.7	<0.01
Asp	85.7^{b}	91	4.1	86.5^{b}	21	3.6	87.9^{ab}	4	0.7	83.5^{b}	7	4.9	86.9^{b}	13	4.5	91.7^{a}	5	3.0	2.0	0.01
Cys	79.0	104	11.8	82.2	16	5.5	81.3	4	5.0	74.5	7	9.3	78.2	13	5.5	78.9	3	12.2	6.2	0.72
Glu	87.3^{c}	92	5.1	88.4^{bc}	21	3.0	91.0^{abc}	4	1.7	82.4^{d}	7	5.2	90.8^{ab}	13	3.5	94.2^{a}	5	3.5	2.3	<0.01
Gly	83.0^{bc}	92	7.6	83.5^{abc}	21	6.8	87.7^{abc}	4	4.6	79.4^{c}	7	4.9	87.5^{a}	13	3.0	89.0^{ab}	5	3.1	3.5	0.04
Ser	86.9^{b}	92	5.8	89.7^{ac}	21	5.4	90.3^{ab}	4	2.0	86.1^{bc}	7	4.8	91.2^{a}	13	3.2	92.7^{a}	5	3.3	2.7	<0.01
Tyr	88.5	68	4.4	86.8	22	9.8	92.9	3	1.2	89.9	6	2.3	92.1	8	3.3	87.7	4	11.6	3.5	0.26

[a–c]Values within a row lacking a common superscript letter are different ($P < 0.05$).

[1]Data include all published values for soy protein ingredients, regardless of the BW of pigs used to determine the values.

The SID of Ala and Ser in SBM 44% was greater ($P < 0.05$) than in SBM 48%, but for all other AA, no differences between SBM 44% and SBM 48% were observed, which indicates that removal of the hulls from soybeans before crushing does not improve the SID of AA. There were also no differences in the SID of AA among SBM 48%, SBM 44%, and FSBM with the exception that the SID of Lys and Glu was less ($P < 0.05$) in FSBM than in SBM 48% and SBM 44%. These observations indicate that although the galactooligosaccharides are removed during production of FSBM (Cervantes-Pahm and Stein, 2010), this does not result in improved SID of AA.

The SID of CP and all AA obtained in pigs less than 20 kg was less ($P < 0.05$) than SID values determined in pigs ranging from 20 to 50 kg BW and also less ($P < 0.05$) than SID values determined in pigs that were above 50 kg, except for the SID of Tyr (Table 2). This observation may be a result of limited capacity for digestion of certain sources of plant protein and absorption of AA in young pigs compared with older pigs (Hedemann and Jensen, 2004; Urbaityte et al., 2009). In contrast, with the exception of Glu and Tyr, no differences between pigs that were 20 to 50 kg and pigs that were greater than 50 kg were observed. This observation indicates that for SBM 48%, the SID of AA is constant in pigs above 20 kg BW, which is in agreement with data indicating that the SID of AA is not different between finishing pigs and lactating sows (Stein et al., 2001). The implication of these observations is that values for the SID of AA in SBM 48% obtained with pigs above 20 kg may not always be representative of the SID of AA in pigs that are less than 20 kg. However, for FSBM, ESBM,

Table 2. Effect of initial BW on standardized ileal digestibility (%) of CP and AA in dehulled soybean meal

Item	<20 kg			20–50 kg			>50 kg				
	No.	Average	SD	No.	Average	SD	No.	Average	SD	SEM	*P*-value
CP	25	80.2[b]	5.0	34	89.0[a]	2.5	10	88.7[a]	2.0	1.1	<0.01
Indispensable AA, %											
Arg	29	91.0[b]	2.9	44	95.1[a]	2.3	10	95.0[a]	0.7	0.8	<0.01
His	29	83.7[b]	4.5	43	91.5[a]	2.0	10	90.6[a]	1.3	1.0	<0.01
Ile	29	83.9[c]	3.6	44	91.1[a]	2.4	10	88.8[a]	2.4	0.9	<0.01
Leu	29	83.0[b]	3.9	44	89.3[a]	2.2	10	87.9[a]	1.6	0.9	<0.01
Lys	29	84.1[b]	3.8	44	90.5[a]	2.2	10	89.4[a]	1.6	0.9	<0.01
Met	29	85.2[b]	3.8	44	91.6[a]	3.2	10	90.2[a]	2.4	1.1	<0.01
Phe	29	86.1[b]	3.1	43	89.7[a]	2.0	10	88.5[a]	1.6	0.8	<0.01
Thr	29	76.6[b]	6.1	44	87.0[a]	2.7	10	85.4[a]	2.1	1.3	<0.01
Trp	29	76.6[b]	7.9	38	91.5[a]	3.2	9	90.5[a]	3.1	1.8	<0.01
Val	29	80.9[b]	4.5	44	88.2[a]	3.1	10	87.0[a]	2.7	1.1	<0.01
Dispensable AA, %											
Ala	25	79.5[b]	4.7	28	87.8[a]	4.6	6	84.9[a]	3.6	1.9	<0.01
Asp	25	82.3[b]	3.8	28	88.9[a]	2.9	6	86.3[a]	1.5	1.3	<0.01
Cys	25	63.1[b]	13.7	41	84.6[a]	3.7	10	83.1[a]	3.0	2.7	<0.01
Glu	25	83.0[c]	5.0	28	91.5[a]	3.0	6	87.8[b]	2.7	1.6	<0.01
Gly	25	77.5[b]	7.2	28	87.9[a]	5.0	6	87.7[a]	6.1	2.5	<0.01
Ser	25	82.6[b]	4.8	28	91.2[a]	5.0	6	89.1[a]	2.6	1.9	<0.01
Tyr	7	89.7[ab]	2.2	22	90.8[a]	1.8	6	88.2[b]	1.7	0.8	0.02

[a–c]Values within a row lacking a common superscript letter are different ($P < 0.05$).

and SPI, the data in the published literature are obtained using pigs that are less than 20 kg.

In conclusion, based on the present analysis, it is evident that differences in values for SID among different sources of soy protein exist, which implies that different processing procedures influence the digestibility of AA in soy protein. In addition, at least for SBM 48%, there appears to be an effect of the age of the pig on the digestibility of AA, with pigs being less than 20 kg having a reduced digestibility of most AA compared with pigs that are above 20 kg. It may, therefore, not always be accurate to use SID values obtained in older pigs and apply them to younger pigs.

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